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Bariatric surgery: Rhabdomyolysis after open Roux-en-Y gastric bypass: A prospective study

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ABSTRACT

Background: Rhabdomyolysis (RML) is a recently recognized complication of bariatric surgery (BS). The aim of this prospective study was to determine frequency, risk factors, and clinical relevance of RML in morbidly obese patients treated with open Roux-en-Y gastric bypass (RYGBP).

Methods: A total of 23 consecutive patients with morbid obesity undergoing primary open RYGBP were included prospectively in the present study. The following parameters were recorded: age, gender, BMI (kg/m^2), comorbidities (presence of known hypertension and diabetes), duration of surgery, levels of serum creatine phosphokinase (CPK) measured before surgery and daily after until the values were clearly tending towards normal, and the presence of neuromuscular symptoms in the early post-operative period. RML was defined as post-operative CPK >1000 IU/l (5 times the normal value). Patients were divided into two groups according to the presence or absence of RML.

Results: The study sample consists of 16 females (69.6%) and 7 males (29.4%). RML was diagnosed in 7 (30.4%) patients with CPK levels greater than 5000 IU/l in 3 patients (42.9%). BMI was identified as an independent risk factor for RML ($P = 0.031$). The best cut-off value of BMI as a predictor of RML was 55.88 kg/m^2 giving sensitivity of 100% and specificity of 80.7%. Other variables (age, sex, comorbidities, and duration of surgery) did not have a significant predictive effect on the rate of RML.

Conclusion: After open bariatric surgery with RYGBP, the risk of RML increases in obese patients specially when BMI >56 kg/m^2. In such patients, CPK, which is an inexpensive easily done test, should be performed routinely to guarantee early diagnosis and consequently preventive treatment of RML complications.

1. Introduction

Overweight and obesity are estimated to be present in 1.7 billion people in the world. It is estimated that 25 million of deaths per year in the world are related to overweight.[1] Obese patients face an increased risk of coronary deficiency, arterial hypertension, dyslipidemia, diabetes, sleep apnea syndrome, and psychologic disorders. The US Department of Health and Human Services and the World Health Organization have defined overweight as a body mass index (BMI) >25 kg/m^2 and obesity as a BMI ≥30 kg/m^2, with class I obesity – BMI 30.0–34.9 kg/m^2, Class II obesity – BMI 35.0–39.9 kg/m^2 and Class III obesity – BMI ≥40 kg/m^2.[2] Surgery is proposed to treat Class III obesity or Class II obesity in the presence of comorbidities.[3]

Perioperative complications affecting bariatric patients can be as high as 30%.[4,5] Complications such as gastrointestinal leaks, local infection, atelectasis, and thromboembolism are well documented.[6,7] A less known post-operative complication, rhabdomyolysis (RML) was observed recently.[6–8] RML can be defined as a disorder that consists of striated muscle disintegration resulting in the release of muscle toxic cell constituents (creatine kinase and myoglobin) into extracellular fluid and systemic circulation challenging the kidney's filtering system. According to the extension damage, it can be asymptomatic or life threatening due to the possibility of hypovolemia, electrolyte disturbs, coagulopathy and renal failure. Volume depletion resulting in renal ischemia, tubular obstruction due to heme pigment casts, and tubular injury from free unchelated iron, all contribute to the development of renal dysfunction.[9–12] Because muscle cell lysis-induced acute renal failure comes with a 20% mortality,[13] early diagnosis of RML is extremely important. Management should be based around the principles of prevention; however should rhabdomyolysis develops then early recognition and prompt treatment should be instituted to minimize renal and muscular damage.[14] Preventive measures to avoid RML are padding pressure areas; use of pneumatic mattress during operation; optimal positioning on surgical table; frequent

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Table 1
Characteristics of patients with (+) and without (−) rhabdomyolysis and global values.

	RML+ (no. = 7)	RML− (no. = 16)	*P*	Global values (no. = 23)
Age (years)	32.43 ± 7.93	34.06 ± 7.42	0.65[a]	33.57 ± 7.44 (20–46)
Sex (female/male)	3F/4M	13F/3M	0.14[b]	16F/7M
Weight (kg)	183.86 ± 23	142.19 ± 13.59	0.002[a]	154 ± 25.58 (119–211)
Height (cm)	168.28 ± 10.51	168.06 ± 8.96	0.96[a]	168.13 ± 9.21 (154–185)
BMI (kg/m^2)	64.8 ± 4.37	50.58 ± 5.92	<0.001[a]	54.91 ± 8.59 (39.30 ± 69.05)
Duration of operation (min)	256.42 ± 21.54	250.62 ± 16.11	0.53[a]	252.39 ± 17.63 (225–280)
CPK Preop (IU/l)	113.57 ± 43.75	87.5 ± 43.89	0.21[a]	95.43 ± 44.56 (35–165)
CPK Postop (IU/l)	6857.14 ± 4817.97	347.18 ± 152.55	0.01[a]	2328.5 ± 3965.7 (110–13,500)
Hypertension	3/7	7/16	1.00[b]	10/23
Diabetes mellitus	1/7	2/16	1.00[b]	3/23

M, male; F, female.
[a] Mann–Whitney test.
[b] Fischer's test.

change in surgical table position to use gravity to facilitate retraction of tissues to improve what is seen in the operative field which has the *byproduct* of changing the pressure that develops under each muscle compartment; limit surgical time by performing surgery in two stages; avoid early in the learning curve selecting high-risk super-super-obese patients; aggressive fluid replacement perioperatively; and early ambulation after surgery.[15–17] Although the underlying mechanism of RML has not been well defined, high superficial pressures on the surgical table seem to be involved.[14] RML in BS has been previously described mainly as case reports[6–8,12,18,19] with just a few longitudinal studies about its frequency.[10,17,20,21]

The aim of this prospective study is to determine frequency, risk factors, and clinical relevance of RML in morbidly obese patients treated with open Roux-en-Y gastric bypass (RYGBP) and compares it with available studies.

2. Patients and methods

From July 2007 to December 2009, a total of 23 consecutive patients with morbid obesity undergoing primary open RYGBP performed by the same surgeon at Endocrine Surgery Unit, Mansoura University Hospital were enrolled prospectively in the study. The inclusion criteria were morbidly obese patients with BMI ≥40 kg/m^2 or BMI ≥35 kg/m^2 with comorbidities in whom dietary and medical therapies had failed. The exclusion criteria were abnormally elevated preoperative creatine phosphokinase (CPK), history of muscle disease, treatment by statins or other lipid lowering drugs and alcohol addiction. The following parameters were recorded: age, gender, weight (kg), height (cm), BMI (kg/m^2), comorbidities (presence of known hypertension or diabetes (DM)), duration of surgery, levels of serum CPK measured before surgery and daily after until the values were clearly tending towards normal; usually 5 days, and the presence of neuromuscular symptoms in the early post-operative period.

The protocol of anaesthesia was standardized. Patients were premedicated with a midazolam (0.08 mg/kg). Anesthesia was usually induced with fentanyl (1 μg kg) and sodium thiopental (5 mg/kg), and muscular relaxation was achieved with atracurium (0.5 mg/kg). After the trachea was intubated, anaesthesia was maintained with isoflurane.

All patients in the present study underwent open RYGBP. Patients were placed in the supine position with adequate padding of the buttocks, lumbar region and shoulders to avoid muscular injuries. Abdominal incision was marked, started from xiphoid process to 5 cm above the umbilicus. Creation of a 15–30-ml gastric pouch was done using a 90 mm Linear Stapler (Ethicon Endo-Surgery, INC, USA). The jejunum was divided 50 cm beyond the ligament of Treitz. End-to-side jejunojejunostomy was performed manually in 2 layers 140–150 cm from the initial point of jejunal division. Side-to-side anastomosis was performed manually in 2 layers between the gastric pouch and the Roux limb to create a stoma of 1-cm. Drainage was routinely provided. Frequent change in surgical table position was done during the operation. Intraoperative intravenous fluid administration was kept at 12 ml/kg/h and UOP was maintained at >2 ml/kg/h. The duration of surgery was measured in minutes with exclusion of anaesthesia time needed for induction and recovery.

The CPK measurements were performed using Human Gmbh kit, Germany. The reference (normal) level ranged from 0 to 195 IU/l. Serum CPK 5 times the upper normal value without apparent cardiac or brain injury was considered as a biochemical diagnosis of RML[13,23,24] corresponding to serum CPK levels >1000 IU/l. Considering the risk of renal failure, patients with post-operative CPK >5000 IU/l were preventively treated by aggressive fluid replacement, forced diuresis and alkalinization of urine with monitoring of blood urea nitrogen, serum creatinine and urine volume daily.

Post-operative care included admission to ICU for 24 h followed by transfer to surgical ward unless RML was confirmed where patients with elevated CPK levels stayed in ICU till CPK levels were tending towards normal. The patients were nursed in semisitting position. Blood tests were performed after the operation including complete blood count, serum electrolyte, blood gases BUN/serum creatinine and serum CPK levels. Prophylaxis of venous thrombosis was conducted by enoxaparin (Clexane) 60 mg subcutaneously daily for 5 days and by compression stocks; no intermittent compression of the legs was used. Intravenous fluid administration was maintained for the first 3 post-operative days. Oral fluid intake was started on the 4th post-operative day. Post-operative pain was controlled with acetaminophine (40 mg/kg, maximum 4 g/day) and/or morphine (30 μg/kg) depending on the complaints; no epidural analgesia was used. Meticulous control of hypertension and diabetes (if present) was done. Gradual ambulation was started 24 h after surgery unless ambulation was limited by pain where physiotherapy protocol was scheduled.

The results are expressed as mean values with standard deviation. Fischer Exact test and Mann–Whitney test were used to compare groups. Stepwise logistic regression was used for the multivariate analysis. ROC curve was used to evaluate BMI as a predictor parameter of RML. Kendall's test was performed to correlate post-operative CPK levels with other variables. *P*-values < 0.05 were considered statistically significant.

3. Results

The study sample consists of 16 females (69.6%) and 7 males (29.4%). Patients' characteristics are shown in Table 1. Hypertension was present in 10 patients (43.5%) and DM in 3 patients (13.1%). Mean duration of surgery was 252.39 ± 17.63 min (range 225–280 min). Mean CPK level in the preoperative period was 95.43 ± 17.63 IU/l (range 35–165 IU/l). The highest elevation of CPK was found on the first post-operative day (2328.5 ± 3965.7 IU/l,

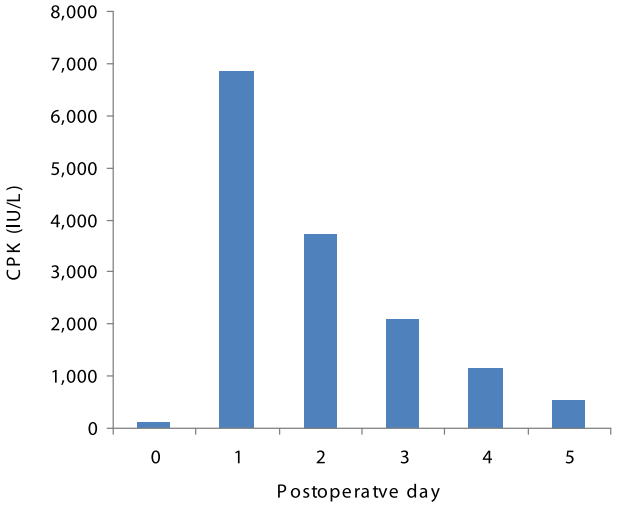

Fig. 1. Average CPK levels of patients who developed RML.

Table 2
Multivariate logistic regression for RML risk factors.

Variable	Regression coefficient (*B*)	S.E. of *B*	*P*	CI 95%	
				Minimum	Maximum
Constant	−2.257	–	<0.001	−3.09	−1.418
BMI	0.025	0.462	0.031	0.003	0.048
Weight	0.007	0.412	0.051	0.001	0.015

range 110–13,500 IU/l). Serial CPK measurements of patients who developed RML are shown in Fig. 1.

RML was diagnosed in 7 patients (30.4%) with CPK levels greater than 5000 IU/l in 3 patients (42.9%) who exhibited muscular pain. It was located mainly in the gluteus and lumbar areas and to less extent in shoulders. No other symptoms were exhibited. No patient progressed to compartment syndrome or muscle necrosis, thus decompression maneuvers and surgical debridement were not necessary. All patients survived and no one developed acute renal failure.

Comparative analysis between patients with and without RML showed statistical significance in the mean weight and mean BMI (Table 1). On multivariate analysis, only BMI was identified as the sole significant independent risk factor for RML development (Table 2). Comparison of the results of the present study to the results of other available longitudinal studies is provided in Table 3.

Using receiver operating characteristic (ROC) curve analysis, the best cut-off value of BMI as a predictor of RML was 55.88 kg/m^2 giving sensitivity of 100% and specificity of 80.7%.

Nonparametric Kendall's correlation was used to test the linear relationship between post-operative CPK and age, BMI, and surgical duration. Only BMI showed highly significant positive correlation with post-operative CPK ($r_b = 0.515$, $P < 0.001$) (Fig. 2).

4. Discussion

RML was originally observed in traumatology as a crush injury and after prolonged stable position.[25] Nevertheless, just localized pressure over muscle groups of the shoulders, back, buttocks and lower limbs, generated during several hours by gravity forcing a massive body against an unyielding surgical table, may be sufficient for damage of muscle sarcolemma and leakage of intracellular content into the circulatory system.[9,10,12,26] Compartment syndrome may be an early or late complication that results mainly from direct muscle injury.[7,14] Large amounts of intravascular fluid become sequestrated as edematous fluid in damaged muscle tissue and the condition may progress to compartment syndrome.[27] Compartment syndrome may also develop or worsen during fluid resuscitation due to development of edema of the limbs and/or muscles. Decompression fasciotomy, muscular debridement and escharotomies should be considered in patients with evidence of neurovascular compression and decubitus ulcer.[7,14,28] Renal damage is at high risk with incidence of 30–50%.[29] CPK is the most sensitive enzyme marker for muscle injury[23] which is present in 100% of RML cases[14] and is readily determined in most laboratories. Among the many causes of RML,[12] pressure-induced RML has been reported in surgeries of obese and nonobese patients undergoing surgical procedures.[7–9,30,31] Recent reports indicate a strong association of RML with BS.[8,32] Bariatric patients are at high risk of developing RML with a frequency varying from 1.4 to 77.3%.[10,17,18,20–22] In the present study, post-operative RML was diagnosed in 30.4% of patients. This frequency is close to that reported by Carvalho et al.[21] (37.7%) after open RYGBP, Mognol et al.[10] (22.7%) after laparoscopic gastric banding and RYGBP and Lagandre et al.[20] (26.5%) after laparoscopic gastric banding and open intestinal bypass as the primary BS. The highest frequency reported for RML after BS was 77.3% by de Oliveira et al.[22] after open RYGBP. This wide discrepancy may be explained by, first, the protocol of anaesthesia was not standardized as the authors did not report the exact anaesthetic medication, second, the different diagnostic criteria for RML (CPK level >675 IU/l for women and 850 IU/l for men) who may overestimated the prevalence of patients with RML in their study and third, it was not reported whether statins intake was stopped preoperatively and if, for how long. It is known that specific medication and drugs may lead to RML especially propofol which interferes with oxidative energy production. Furthermore RML is a known side effect of statins especially in obese patients through inhibition of cholesterol and mevalonate synthesis in proportions of <0.1% of treated patients.[7,33] In their retrospective study, Ettinger et al.[17] reported RML after laparoscopic and open RYGBP with a frequency of 7%. This low frequency may be attributed to low mean BMI (43.1 kg/m^2) of their patients and the very short operative time (176.7 min) reported. RML was also reported after sleeve gastrectomy in a male patient with BMI of 54.3 kg/m^2 and operative time of 180 min.[34]

Risk factors for RML in bariatric surgery include the degree of obesity,[10] long duration of surgery,[10,14,16] male gender,[21,24] presence of hypertension,[24] diabetes[16,20,24] and ASA-physical status > II.[16,20] The only risk factor identified for RML development in our patients was BMI (BMI >55.88 kg/m^2). This may be explained by

Table 3
Longitudinal studies of RML after BS.

	Mognol et al.[10]	Ettinger et al.[17]	Lagandre et al.[20]	Carvalho et al.[21]	de Oliveira et al.[22]	Present study
Number of patients	66	114	49	98	22	23
Surgical technique	• Lap RYGBP (16) • Lap GB (50)	• Open RYGBP (56) • Lap RYGBP (58)	• Lap GB (32) • Open BPD/DS (13) • Open RYGBP (4)	Open RYGBP	Open RYGBP	Open RYGBP
Age (years)	39.0	38.25	39.9	37.4	39.9	33.5
Sex (female %)	75	75.4	73.4	64.3	63.6	69.6
BMI (kg/m^2)	58.8	43.1	51.0	43.2	52.4	54.9
Hypertension (%)	22.7	–	–	–	63.6	43.5
Diabetes (%)	19.6	–	36.5	–	13.6	13.1
Surgical time (min)	390	176.7	233.5	216	253	252
RML (%)	22.7	7	26.5	37.7	77.3	30.4
Post-operative CPK (IU/l)	7890	400	1386 (RML+)	1075.2	7467.7	2328.5
Diagnostic criteria of RML	CPK >1000 IU/l in both sexes	CPK >950 IU/l in both sexes	CPK >1000 IU/l in both sexes	M: CPK >1160 IU/l F: CPK >1075 IU/l	M: CPK >850 IU/l F: CPK >675 IU/l	CPK >1000 IU/l in both sexes
Identified risk factor for RML	• Massive obesity • Long duration of the operation	BMI	Surgery time >4 h	Male gender	Long surgical time	BMI
Type of the study	Prospective	Retrospective	Prospective	Retrospective	Prospective	Prospective

Lap, laparoscopic; GB, gastric banding; BPD/DS, biliopancreatic diversion with duodenal switch; RYGBP, Roux-en-Y gastric bypass.

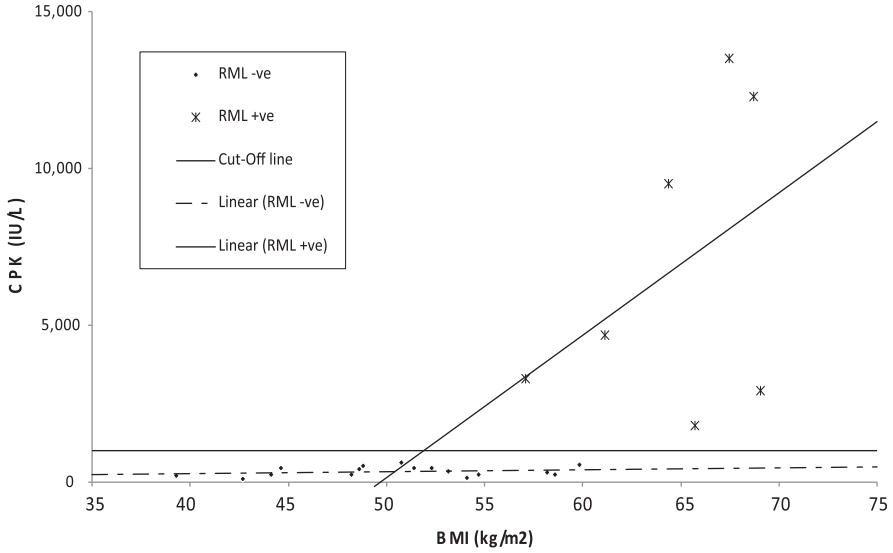

Fig. 2. Correlation between BMI and CPK in RML+ and RML− groups at 24 h. The figure shows that significant correlation between BMI and CPK is mainly due to the variability within RML+ group with the continuous trend line. The RML− case has dashed line almost parallel to base line. The dotted line represents the cut-off value of CPK between RML+ and RML− cases.

high-unrelieved muscle pressure while on the operating table, with creation of a compartment compression with resultant ischemic alterations. This similar finding was reported in *two* previous studies in which BMI >60 kg/m^2 [10] and >50 kg/m^2 [17] was reported as a risk factor for RML.

Comorbidities in the form of hypertension (43.5%) and diabetes (13.1%) were present in our patients. High frequency of these comorbidities in relation to obesity was also reported in previous studies.[10,22] Furthermore, presence of these comorbidities is a criterion of selection for BS in patients with BMI <40 kg/m^2. Hypertension and diabetes lead to chronic microcirculation abnormalities and they may increase the risk of RML after BS.[10,16,20] Neither of these two factors could be identified as risk factors for RML in our study in spite of the frequency of these comorbidities in our patients.

Male gender as a risk factor for development of RML in BS was identified in previous studies[21,24] and was explained by the larger muscle mass in men. In the present study, the frequency of RML in males was higher than in females but it failed to reach a statistical significant level. With more cases such difference may be significant as males showed significantly higher CPK after surgery than females ($P = 0.01$).

The mean surgical time in our study was relatively short (252.39 min), similar to that reported by Carvalho et al.[21] (216 min) and de Oliveira et al.[22] (253.2 min) but lower than what was reported by Mognol et al.[10] (390 min). Our study did not show any statistical significance between surgical time and development of RML, similar to what was reported by Carvalho et al.[21] and in contrast to that reported by Mognol et al.[10] and de Oliveira et al.[22] who showed that prolonged surgical time increased the risk of RML. Less prolonged operations are always advisable[8,24] despite lack of statistical differences in the present study.

The peak of CPK elevation in our study occurred on the first day after surgery. This finding was similar to that reported by Mognol et al.,[10] Lagandre et al.,[20] and Carvalho et al.[21] but differs from that reported by Bostanjian et al.[24] and Faintuch et al.,[35] that CPK peaks occurred on the second post-operative day. In only one previous study by Ettinger et al.,[17] the highest CPK levels were recorded on the third day after surgery.

Diagnosis of RML requires a high level of physician awareness. The symptoms and signals commonly encountered include muscular pain,[8,10,12,18,20,24] numbness, distal muscle weakness[19] and meralgia paresthetica.[36] Muscular pains were present in 3 patients (42.9%) among the seven patients diagnosed as having biochemical RML. All of the three patients had CPK levels >5000 IU/l and muscular pains were exhibited mainly in the gluteus and lumbar areas and to less extent in shoulders.

Early diagnosis of RML may have significant impact on outcome by halting or reducing its complications. When diagnosis is delayed and appropriate treatment is not instituted, serious complications such as hyperkalemia, hypocalcemia, hyperphosphatemia, compartment syndrome, cardiac arrhythmias, disseminated intravascular coagulation, acute renal failure with multi-system organ failure, and even death can occur.[17,18] Permanent dialysis for RML-induced renal failure following BS was reported.[37] Bostanjian et al.[24] instituted aggressive hydration and manitol when patients' CPK levels were ≥5000 IU/l. According to these investigators, the chance of complications caused by muscle necrosis when CPK levels ≤5000 IU/l is minimal. In the present study 3 patients exhibited CPK levels >5000 IU/l and were preventively treated by aggressive fluid replacement, forced diuresis and alkalinization of urine with monitoring of blood urea nitrogen, serum creatinine and urine volume daily. All patients survived and no acute renal failure occurred.

One limitation of the present study is the small sample size; nevertheless the possible advantage of this contribution is the prospective nature of the study. Future prospective controlled multicenter trials including a collection of all reported data could confirm and reach a consensus regarding risk factors, pathomechanism and treatment of RML following BS.

According to the present study, we suggest CPK measurements to be carried out in bariatric patients undergoing BS with BMI >56 kg/m^2 to early detect CPK elevation which could progress to RML to avoid its severe potential complications. This is in accordance with data from previous retrospective and prospective studies suggesting that CPK measurements to be carried out when BMI >50 kg/m^2 [17] and >60 kg/m^2 [10] respectively.

5. Conclusion

After open bariatric surgery with RYGBP, the risk of RML increases in obese patients specially when BMI >56 kg/m^2. In such

patients, CPK, which is an inexpensive easily done test, should be performed routinely to guarantee early diagnosis and consequently preventive treatment of RML complications.

Conflict of interest

None.

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None declared.

Ethical approval

Ethical Approval from MEC number MFM 20114678120.

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